Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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IOP Conf. Series: Journal of Physics: Conf. Series **1177** (2019) 012055 doi:10.1088/1742-6596/1177/1/012055

Peculiarities of strained state of the buggy undercarriage under torsional loading

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Abstract. This paper deals with the traits of strained state of buggy undercarriage torsional loading. The buggy undercarriage represents a tubular space frame consisting of round cross-section elements. The strained state of the buggy space frame can be characterized by a number of specific features such as: a centerline distortion and front sub-frame cross-sections twisting about their own pivot points. The possible reasons for it are considered as well as their negative effects. Practical recommendations to minimize the negative effects are proposed. All the represented results are obtained with the help of a computer simulation technique based on the finite element method.

1. Introduction

Tubular space frame is the main carrying structure of the most buggy cars represented on the market. It means that the frame should carry all the variety of the external loads that occur during driving. In addition, the frame bears loads from the power train and all the aggregates and elements of the car. Both mentioned facts place special demands on the carrying ability of the buggy space frame. It is necessary to bear in mind that buggy cars are tend to be used for a cross-country drive and it seems to be obvious that the frame undergoes combined loads which results in frame combined stress state. Therefore it is very important to investigate the most typical load cases for the construction studied. The importance of being aware of the relevant load cases can be explained by the necessity to understand the frame elements behavior under loading because as it has already been mentioned – frame elements bear the power train aggregates and the suspension attachment points. Deformations and displacements in such points can lead to aggregate damage or distortion of suspension motion characteristics. Analysis of a number relevant studies [1, 2, 5, 6, 7] shows that the most tough of the typical load cases for buggy frames is torsion.

2. Load case torsion

The boundary conditions for the torsional loading of the buggy frame are depicted in the figure below [3, 7].

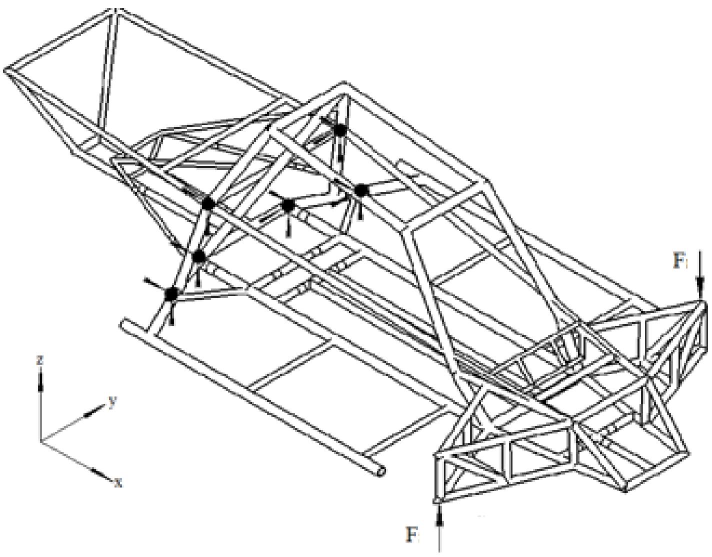

Figure 1. Boundary conditions for the load case torsion

As it can be seen the frame can be characterized by a spatial arrangement of its elements. All the elements have round cross-sections of different diameters and are made of AISI C1020 steel in this case . The triangle suspension arms on the computer model are rigid and attached to the frame in order to transfer a torque to it. The loading magnitude is chosen to the effect that the frame deforms in an elastic stage. The fixtures are applied to the rear suspension mounting points.

The frame can be divided into three substructures as shown in the example of the typical D2 Buggy layout:

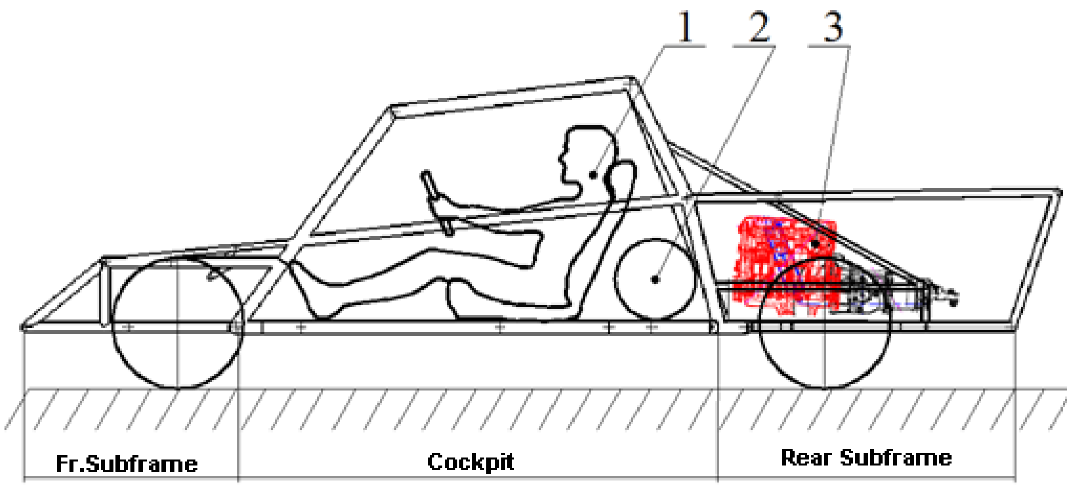

Figure 2. D2 Buggy layout and division into three substructures: 1 – driver; 2 – fuel tank; 3 – engine

The front subframe bears front suspension mounting points and if required – a front differential. Cockpit houses a driver and a fuel tank. Rear subframe carries an engine and a gearbox. Rear suspension mounting points can be either on the cockpit or on the rear subframe.

The conducted experiments revealed that the front subframe cross-sections twist about their own pivot points each of those does not coincide with the center line of the frame. This conclusion comes from the analysis of the cross- and longitudinal members displacement picture:

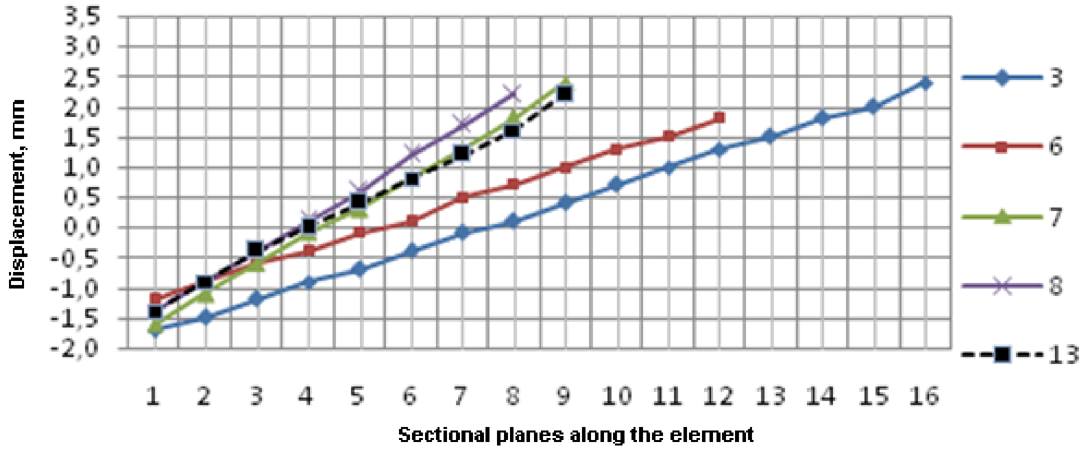

Figure 3. Displacements along Y-axle for the cross-members of the front subframe

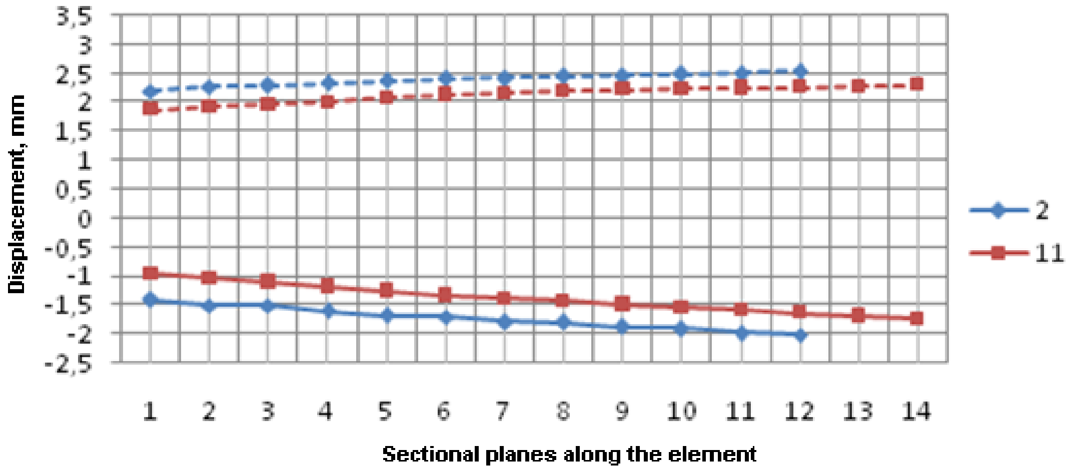

Figure 4. Displacements along Y-axle for the longitudinal members of the front subframe

On the Figure 3 can be seen that the cross-members of the front subframe do not reveal any deformations, they rotate as a unit about some pivot points. These pivot points neither coincide with the center line of the frame nor with each other. The members of the front and middle part of the front subframe 8, 7, 13 are arranged relatively close to each other and therefore have a similar displacement pattern. The back-end members 3 and 6 turn at a smaller angle. Figure 4 shows that the displacement patterns of the longitudinal members on both sides are equal, on the right side though (full lines) the amplitudes are a bit greater. With all that in mind one can come to the conclusion that the pivot points of the front subframe cross-sections don’t coincide with the center line of the frame. For this reason it was attempted to build a line containing all these pivot points:

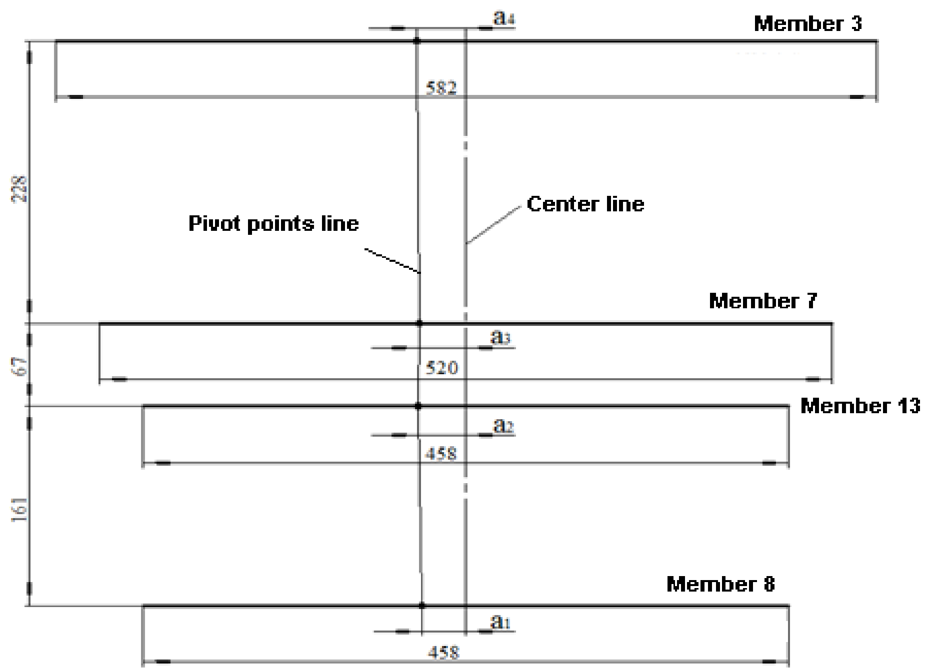

Figure. 5. A line containing pivot points of the cross-sections in the front subframe

The distances between the center line and pivot points line is lettered with a_1, a_2, a_3, a_4 and $a_1 < a_3 < a_2 < a_4$. In order to become a more complete overview over the deformation pattern of the whole front subframe one should take a closer look at the behavior of the vertical elements 9. The displacement diagram of these elements is presented below (one on the right side):

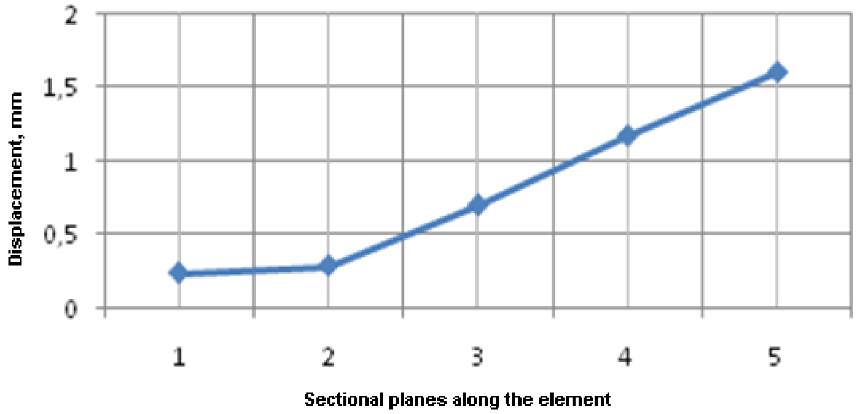

Figure 6. Displacement diagram along the Z-axle for the element 9 of the front subframe (Sectional plane 1 corresponds to the higher point of the element)

As one can see the deformation reaches its maximum at the floor area of the subframe. That means that the cross-sections reveal substantial distortions during their twisting. Pictorially the distortion pattern can be shown as follows:

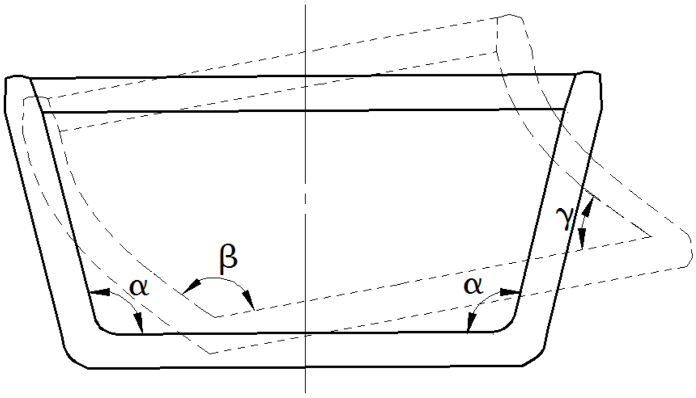

Figure 7. Front subframe cross-section distortion

Such behavior could be explained by the fact that the vertical elements 9 are not able to withstand occurring stresses. In other words the lack of rigidity leads to such deformation by torsional loading. This circumstance can drastically affect the suspension parameters and therefore a car behavior.

In the cockpit area deformation pattern reveals substantially more complex behavior:

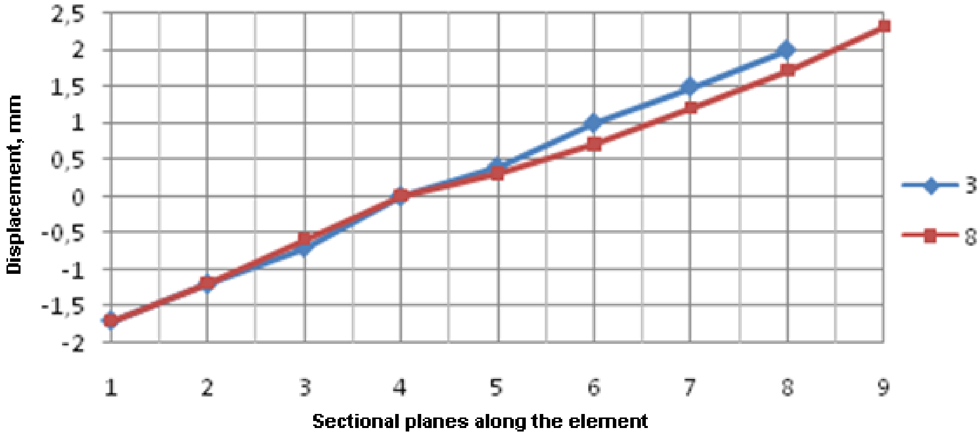

Figure 8. Displacements along the Y-axle for the cross-members of the cockpit

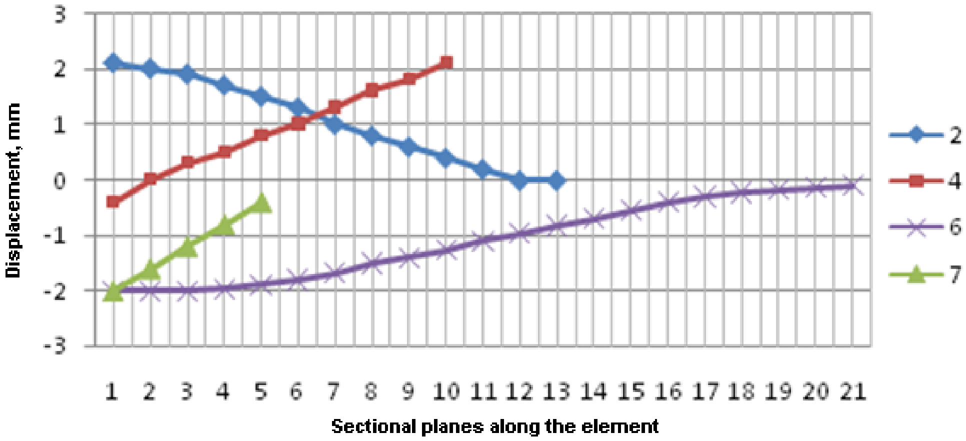

Figure 9. Displacements along the Z-axle for vertical (4, 7) and longitudinal members of the cockpit (for vertical elements the first sectional plane corresponds to the higher point of the element, for the longitudinal ones – to their front end)

The cross-members of the cockpit show the similar behavior to those in the front subframe: they tend to rotate as a unit around some pivot point. The vertical elements however show no signs of deformations – unlike vertical members of the front subframe. Instead they turn at some angle as a whole. Much more complex is the displacement pattern in the longitudinal elements, where considerable deformations occur. It is worth to mention that the displacement distribution in upper and lower elements differs significantly.

3. Conclusion

Based on the analysis above, one could finally outline the causes of the front subframe cross-sections distortion and the pivot points line distortion. The first reason is the unability of the vertical members 9 of the front subframe to block the displacements in the floor area that leads to an undesirable deflection of the suspension mounting points. Secondly, the lack of rigidity of the cockpit longitudinal elements. Due to their length it is possible for a whole cockpit and a front subframe to deflect in a cross direction. This circumstance reveals the lack of rigidity of the cockpit as a whole. In order to minimize or avoid such an unfavourable deformation pattern some construction improvement primarily in the cockpit area is needed to be done.

Appendix

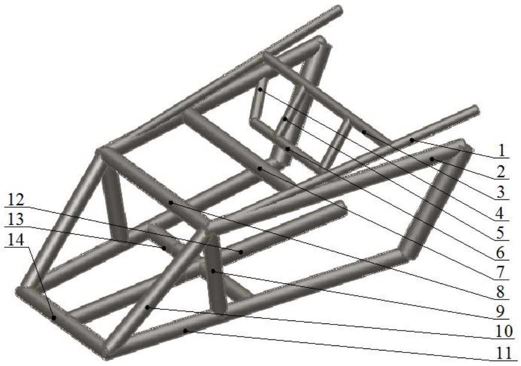

Figure 10. Front subframe

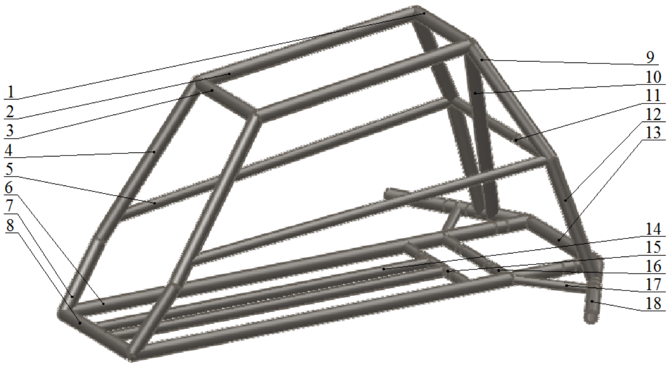

Figure 11. Cockpit

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